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LF AND MF SKY-WAVE PROPAGATION: the origin of the Cairo curves

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Summary

The report describes the measurements from which the Cairo curves were derived. Both curves appear to be 10 dB higher than the measurements indicate, at the greatest distance for which they are drawn. The North-South curve may have been influenced by sea gain and the East-West curve by solar activity.

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L.F. AND M.F. SKY-WAVE PROPAGATION: THE ORIGIN OF THE CAIRO CURVES

P. Knight, M.A., Ph.D., M.I.E.E.

1. Introduction

Many aspects of radiowave propagation were studied before World War 2 and international measurement campaigns were organised. Measurements made at l.f. and m.f. on paths of up to 12,000 km were used to derive the Cairo propagation curves. Measurements on such long paths were possible in those days because of the absence of co-channel interference.

After the war the EBU organised a measurement campaign in Western Europe and produced a set of propagation curves for distances up to 3,500 km. These curves were adopted by the CCIR with a recommendation that they be used within the European Broadcasting Area and attempts were made to extrapolate them to greater distances and to use them outside Europe but with unsatisfactory results. Post-war CCIR texts make no mention of the Cairo curves and their existence was overlooked for many years. More recently, however, the Asian Broadcasting Union has shown that its own long-distance measurements are more consistent with the Cairo North-South curve than with other propagation curves. Consequently the Cairo North-South curve was adopted by the 1974 L.F./M.F. Broadcasting Conference for use in some parts of Asia.

This report describes the origin of the Cairo curves and the measurements from which they were derived.

2. Historical survey

In 1932 the Madrid International Radiocommunication Conference formed a sub-committee under the chairmanship of Dr. van der Pol to study radiowave propagation at distances between 50 and 2000 km and at frequencies between 150 and 2000 kHz. The sub-committee produced a set of ground-wave curves together with a pair of night-time sky-wave curves valid for the whole of this frequency range.[1] The two sky-wave curves give quasi-maximum and mean field strengths and differ by 7 dB.

The 1932 Madrid sky-wave curves were extrapolated provisionally to 5000 km at a meeting held in Lucerne in 1933, but only the Madrid curves were adopted by the CCIR at the 1934 Lisbon meeting. The CCIR recommended that further studies should be made and these were organised by the UIR (International Broadcasting Union), who reported through the U.K.[2]

The first UIR measurement campaign took place during the winter of 1934/1935 and measurements were made between North America and Europe and between South America and Europe.[3]

The second campaign took place in the following winter and included, in addition, measurements between North and South America and between Europe and Siberia.[3]

The third measurement campaign took place in the winter of 1936/1937. Measurements were made over most of the paths which had been studied in the previous winter.[4]

The results of all three measurement campaigns were discussed at the Bucharest meeting of the CCIR in May-June 1937 but there was insufficient time to prepare a technical report. A meeting of radio-wave propagation experts was therefore held in London in November 1937 (again under the chairmanship of Dr. van der Pol) and two l.f./m.f. sky-wave propagation curves were drawn.[5] One of the curves is for propagation far away from the Earth's magnetic poles; this is known as the North-South curve because it was derived from measurements made on trans-equatorial paths which were predominantly north-south. The other curve is for paths which approach the Earth's magnetic pole and is known as the East-West curve because it was derived from measurements made across the North Atlantic. The two curves were formally adopted by the CCIR at the 1938 Cairo meeting and are therefore known as the Cairo curves.[6]

3. The first measurement campaign, 1934/1935

Measurements of European transmitters were made at two receiving stations near New York and one near Washington. The averages of the quasi-maximum field strengths measured at the three stations, for 1 kW radiated, are given in Table 1. The quasi-maximum was defined at the Madrid conference as the value exceeded for 5% of the time.[5]

TABLE 1

Field strengths measured in the USA

Transmitter	Frequency kHz	Distance from Washington, km	Average quasi-maximum field strength, dB above 1μV/m
Paris	959	6200	−9·1
Rennes	1040	5800	−0·6
Athlone	565	5300	0·2

Measurements were also made in Europe of transmitters in North and South America, the maximum field strengths observed during each measuring period being shown in Fig. 1 of Reference 3. On the North Atlantic paths the field strength was below noise level on more than half the occasions that measurements were attempted but South American stations were observed with greater regularity. Because only maximum field strengths were noted, it is difficult to relate these measurements to those made subsequently. The measurements did, however, draw

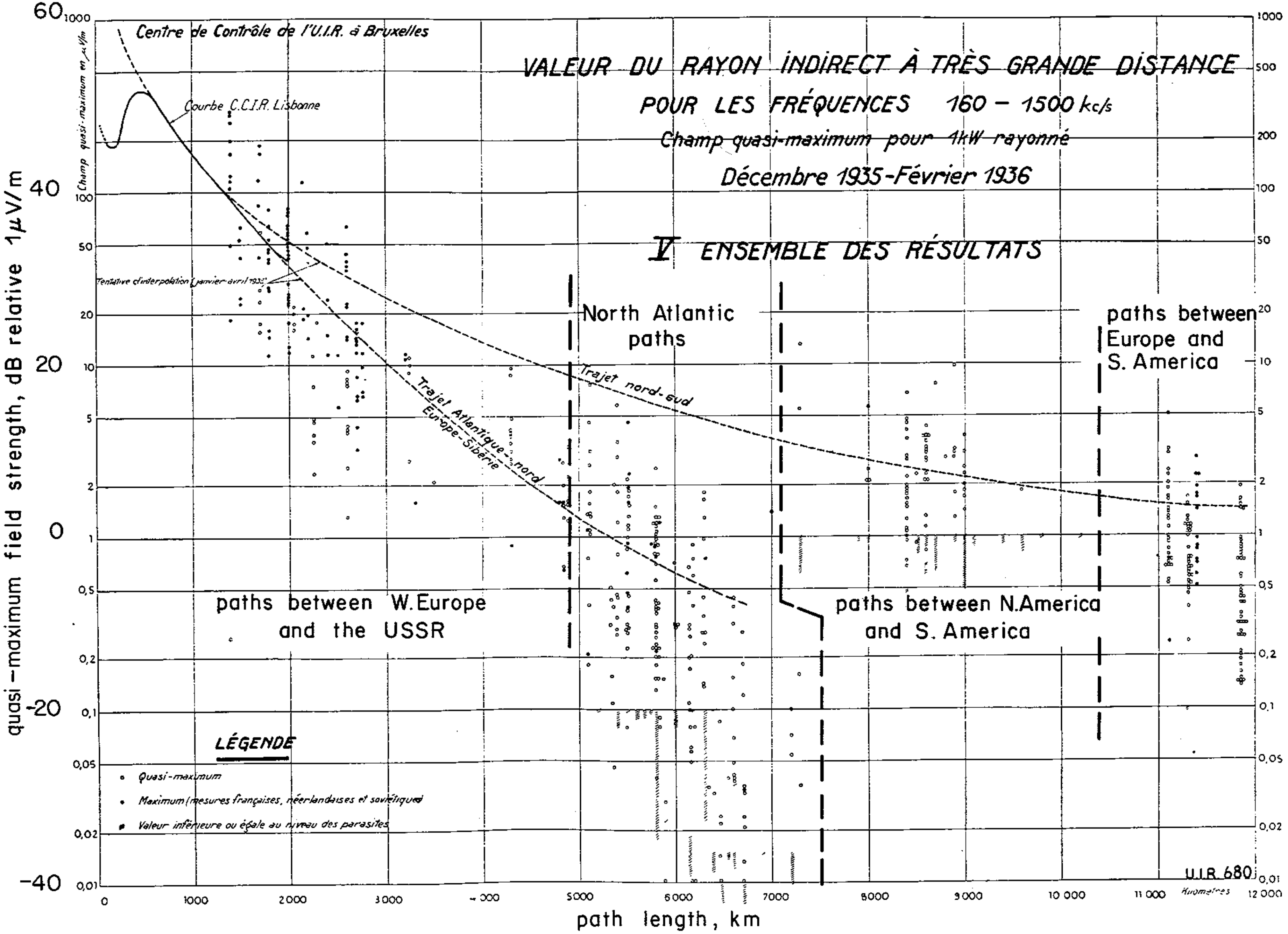

Fig. 1 - Results of the second measurement campaign

TABLE 2

Field strengths measured in 1935/1936

d	F_o	d	F_o	d	F_o
N. America–Europe		S. America–Europe		W. Europe–USSR	
5100	3	11100	1 (a)	1700	28
5400	−10	11300	−3 (b)	2100	25
5500	−1·5	11850	−7 (c)	2250	14
5800	< −20			2600	16
6000	< −20	S. America–N. America		3300	19
6150	< −34			4300	12
6300	< −20	7300	< 0	4800	4
6400	< −36	8400	3·5	4900	4
6450	< −40	8600	2	6200	−3
6600	< −28	8700	< 0		
6700	< −36	9000	< 0		
7200	< −36	9600	< 0		

d = path length, km
F_o = Median of quasi maximum field strengths, for 1 kW radiated, dB above 1μV/m
(a) Buenos Aires – London
(b) Buenos Aires – Brussels
(c) Buenos Aires – Berlin

attention to the difference between North Atlantic and transequatorial paths. Field strengths measured on North Atlantic paths were found to be comparable with those measured on transequatorial paths which were twice as long.

4. The second measurement campaign, 1935/1936

A more extensive series of measurements was carried out in the winter of 1935/1936, between the following geographical areas:

North America and Europe
South America and Europe
Western Europe and the USSR
North America and the USSR

The results obtained on these four types of path are shown individually in Figs. 3 to 6 of Reference 3 and all together in Fig. 7, reproduced here as Fig. 1. Very few of the paths can be identified even though Reference 3 lists all the stations which provided special transmissions. These included three L.F. transmitters in Siberia and one in Holland. The South American transmitters were all located in Buenos Aires and had frequencies between 830 and 1190 kHz. No details of the North American transmitters are given because they were measured during their normal operating periods but Fig. 2 of Reference 3 shows that they were all situated near the east coast and Reference 4 indicates that one was located at New York and had a frequency of 860 kHz. The receiving stations are also listed in Reference 3; those in South America were all located at or near Buenos Aires.

Some of the points in Fig. 1 show peak field strengths and have been disregarded here. Most of the points represent quasi-maximum field strengths measured on individual nights; the median values about which these points are distributed are given in Table 2.

The results again show the considerable difference between transequatorial propagation and east-west propagation at moderately high latitudes. There is no obvious dependence on frequency despite the wide range of frequencies which was observed.

5. The third measurement campaign 1936/1937

This measurement campaign lasted longer than the previous campaigns and was more carefully planned. Measurements were made three times a week for two and a half months. The transmitting stations were selected from those which radiated with high power from half-wave aerials, on frequencies close to 1 MHz. Details of the transmitters and measuring stations are given in Reference 4. Measurements were made between the following geographical areas:

North America and Europe
South America and Europe
North America and South America

All the results are shown in Fig. 2, which is reproduced from Reference 4. For some paths the results are shown by a single point which is the average of the quasi-maximum field strengths which were measured. For other paths the individual quasi-maxima are shown.

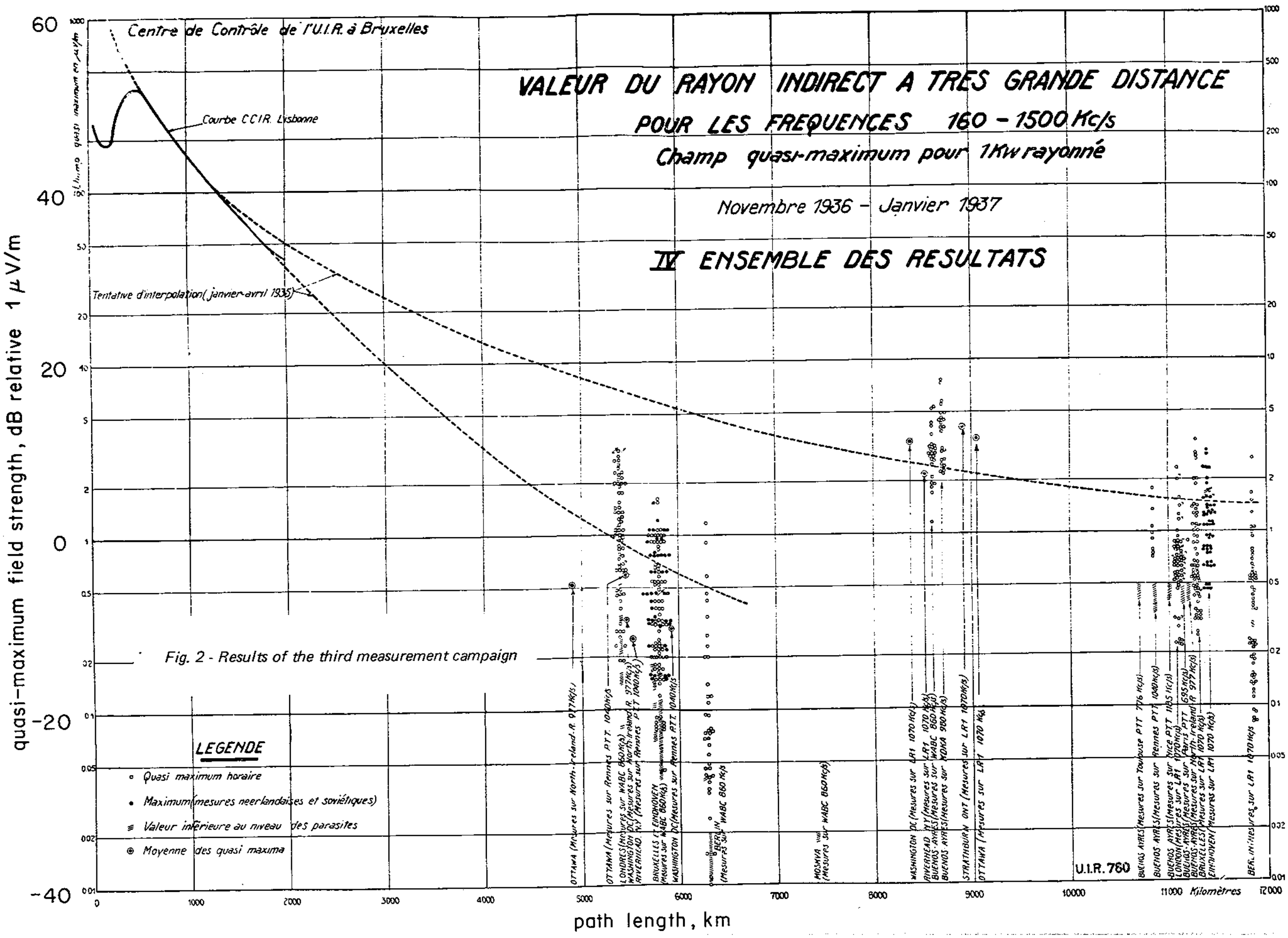

Fig. 2 - Results of the third measurement campaign

TABLE 3

Field strengths measured in 1936/1937

Path No.	Path	Frequency kHz	Path length km (a)	Path length km (b)	Quasi-maximum field strength, dB above 1μV/m
001	Belfast–Ottawa	977	4900	4880	−5·5
002	Rennes–Ottawa	1040	5450	5420	−4·5
003	New York–London	860	5400	5580	−4
004	Belfast–Washington	977	5450	5420	−10
005	Rennes–New York	1040	5500	5600	−12
006	New York–Brussels	860	5800	5900	−14
007	Rennes–Washington	1040	5900	5900	−11
008	New York–Berlin	860	6300	6390	−28·5
009	New York–Moscow	860	7400	7520	< −34
010	Buenos Aires–Washington	1070	8400	8400	10·5
011	Buenos Aires–New York	1070	8500	8500	7
012	New York–Buenos Aires	860	8600	8500	9
013	Pittsburg–Buenos Aires	980	8700	8620	12
014	Buenos Aires–Strathburn	1070	8900	9000	12
015	Buenos Aires–Ottawa	1070	9050	9060	11
016	Toulouse–Buenos Aires	776	10750	10590	< −6
017	Rennes–Buenos Aires	1040	10800	10770	< −6
018	Nice–Buenos Aires	1185	11000	10940	< −6
019	Buenos Aires–London	1070	11100	11120	−4
020	Paris–Buenos Aires	695	11150	11040	−6
021	Belfast–Buenos Aires	977	11200	11100	< −6
022	Buenos Aires–Brussels	1070	11300	11290	−4
023	Buenos Aires–Berlin	1070	11850	11890	−8

(a) as shown in Fig. 2
(b) computed from geographic co-ordinates

The results are summarised in Table 3. Where individual points are shown in Fig. 2, the median about which they are distributed is given in Table 3; this should be almost the same as their average, which cannot be calculated when some of the values are below noise level. The peak field strengths measured at Eindhoven have been disregarded.

Table 2 may be compared with a similar table prepared by the EBU.[7] Small difference between the field-strength columns of the two tables may arise because the EBU, when averaging individual values, seem to have assumed that values below noise level were equal to noise level even though they may have been well below noise level.

6. Interpretation of the measurements

Fig. 3 shows the measurements made across the North Atlantic during all three measurement campaigns, together with the measurements made between W.Europe and the USSR in 1935/36. Also shown in Fig. 3 is the Cairo East-West curve from Reference 5. Fig. 4 compares all the transequatorial measurements with the final version of the North-South Cairo curve[5] which, at 12,000 km, is 3 dB higher than the provisional curve shown in Figs. 1 and 2.

Figs. 3 and 4 show that both Cairo curves give field strengths which exceed most of the measured values. It is possible that the curves were drawn so as to show upper limits but there is no mention of this possibility in Reference 5. A better fit to the measurements would be given if the curves tended towards values 10 dB lower at the greatest distances.

Since l.f. and m.f. sky-wave propagation is usually described by median rather than quasi-maximum field strengths, the Cairo curves have in recent years been reduced by 9 dB to convert them to median values. The 9 dB factor is derived from Reference 5, which states that the median value is about 0·35 of the quasi-maximum. The North-South curve, reduced by 9 dB, is reproduced in Fig. 1 of CCIR Report 575(Rev.76).

All the measurements from which the North-South curve was derived were made on paths which terminated at Buenos Aires and could have been influenced by sea gain, because the estuary of the River Plate is about 50 km wide. At 1 MHz an estuary of this width would give rise to about 6 dB of sea gain on long paths.[8]

The third series of measurements was made near the peak of the solar cycle, when the sunspot number was

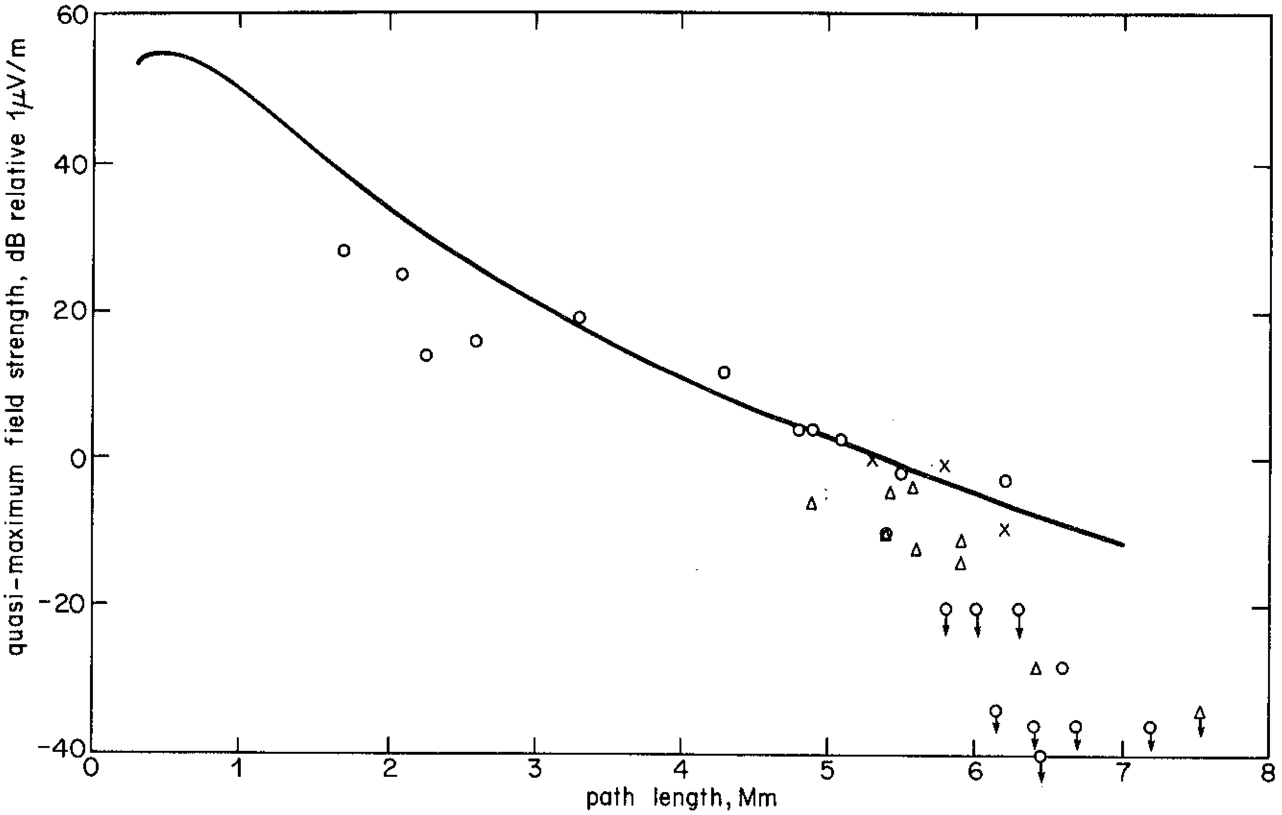

Fig. 3 - Measurements made across the North Atlantic and between Europe and the USSR

X 1934/1935 O 1935/1936 Δ 1936/1937 ——— Cairo East-West curve, from Reference 5

Arrows pointing downward indicate that the actual value was less than the value shown

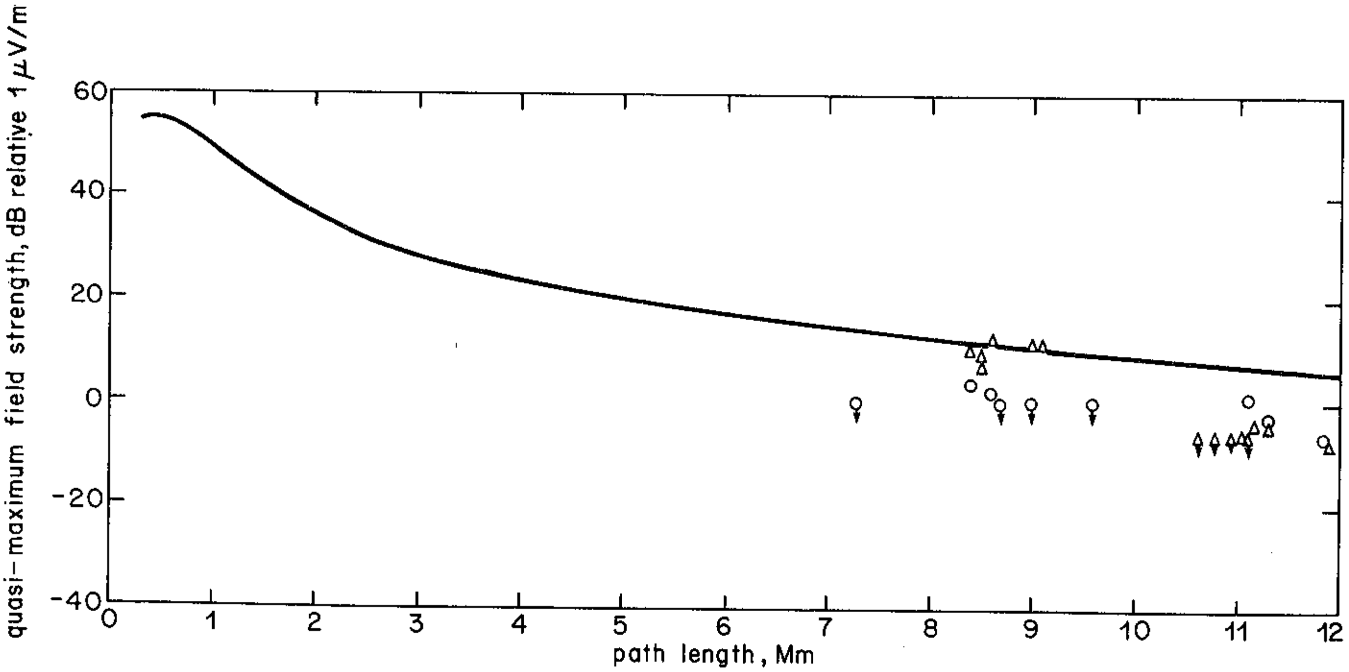

Fig. 4 - Transequatorial measurements

O 1935/1936 Δ 1936/1937 ——— Cairo North-South curve as finally drawn, from Reference 5

Arrows pointing downward indicate that the actual value was less than the value shown about 110. The sunspot numbers for the first and second measurement campaigns were about 50 and 80 respectively. Solar activity is unlikely to have influenced the trans-equatorial paths but may have reduced the field strengths observed across the North Atlantic. Reference 4 notes that lower field strengths were observed in the third series although the reduction is not attributed to solar activity. If the solar-activity correction* for Europe applies to North Atlantic paths, an increase in R from zero to 100 would reduce the field strength by about 5 dB.

7. Conclusions

Both Cairo curves appear to be 10 dB higher than the measurements indicate, at the greatest distances for which they are drawn.

The North-South curve was probably influenced by sea gain; propagation between inland sites might have given field strengths 6 dB lower.

The East-West curve may have been influenced by solar-activity; field strengths on transatlantic paths might be 5 dB greater at sunspot minimum.

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* given in Section 2.6 of the Annex of CCIR Report 575(Rev.76).

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